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July 2, 1979

Mike Thompson  
Division of Oil, Gas and Mining  
1588 W. N. Temple  
Salt Lake City, Utah 84116

Mike;

Enclosed is the most recent evaluation done on the composition of our local groundwater and the water produced in the course of retorting. I would appreciate any comments you may have on the report, the results, or the study methods.

If you have need of any further information on the environmental aspects of our operation please do not hesitate to call me.

Sincerely,

Steve

Steve Grant Mankowski  
Environmental Engineer

enclosures (2)

cc: Vernal  
Concord  
Kamp

~~Route 4 Return to M.T.~~

TJ  
R  
MOW  
JWS



# GEOKINETICS INC.

280 buchanan field road  
concord, california 94520  
(415) 676-4462

## INTEROFFICE MEMORANDUM

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DATE: March 25, 1979

TO: Files

FROM: D. Hutchinson

SUBJECT: GKI Water Quality Studies Progress Report

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Report is attached to this cover sheet.

cc: Concord  
Vernal  
H. Spradlin  
L. Morriss  
S. Mankowski



## GKI WATER QUALITY STUDIES PROGRESS REPORT

### INTRODUCTION

GKI water quality data collected in 1978 and early 1979 was evaluated with the objective of developing preliminary characterizations of native groundwater and retort water at Kamp Kerogen (Section 2, R22E, T14S), Uintah County, Utah.

Restrictive analytical definitions were developed to describe native groundwater and GKI retort water in an effort to eliminate from the sample population both groundwater samples affected by retorting and retort water samples diluted by groundwater.

Native groundwater and retort water sample analyses were subjected to statistical manipulation and testing to summarize the data, to determine the statistical validity of characterizations based on the data available, and to identify probable differences between groundwater and retort water based on available data.

### SUMMARY

1. An evaluation of GKI water quality data related to developing characterizations of native groundwater and retort water at Kamp Kerogen was conducted.
2. GKI retort water and the local native groundwater both appeared to be of very poor quality.
3. Statistical testing indicated that the data available is generally insufficient for conclusive characterizations of native groundwater and retort water.
4. Statistical testing indicated some probable significant differences between native groundwater and retort water that could be determined with available data.
5. Certain parameters should be added to and others deleted from future laboratory analyses suites of water samples.

### BACKGROUND

To enable the reader to obtain an understanding of the context in which GKI hydrological studies have been conducted to date, it is appropriate to provide the following background information:

The geology of Section 2 is dominated by two outcropping members of the Green River Formation; the Parachute Creek Member, and below it, the Douglas Creek Member. The Parachute Creek Member represents sediments deposited in a lacustrine (low energy) environment and is composed of marlstone, oil shale, siltstone, and tuff, with

some sandstone beds. The principle sandstone beds, of which the top beds may be eroded, are found at approximately 5 feet, 40-50 feet, and 70-80 feet, above the alpha oil shale bed.

The Douglas Creek Member represents sediments deposited in a higher energy environment and is composed of sandstone, siltstone, and shale. The thickness and frequency of the sandstone beds increase downward in the section, with the principle aquifers probably in the lowest portion of the member.

A summary assessment of the stratigraphy and lithology of the project site, made from data obtained by coring, supported an assumption that any aquifer capable of yielding sufficient quantities of water suitable for human use or consumption would be located at such a depth that any communication from surface or near-surface water-bearing zones ~~are~~<sup>are</sup> improbable or unlikely. (Martin)

This assumption was supported by the drilling of a well to supply water to the field camp, which was drilled to a depth of approximately 1,300 feet in March, 1978. Coring also established that no significant water-bearing formations below the mahogany zone existed within 300 feet of the surface on or proximate to the project site.

This led to the presumption that concerns of groundwater and water quality would be centered upon perched waters between the surface and the shale deposit being developed. These waters are largely contained in fractures. The presents of such waters was evidenced by some blast-holes filling with water soon after drilling. Blastholes that had been dewatered would often exhibit new accumulations of water within measurably short periods of time. The water levels would often stand at different levels in adjacent holes, indicating no hydraulic communication between the holes.

The probability that water produced by the LOFRECO process, and introduced into the perched water and fracture zones, would be communicated into and contribute to the degradation of a significant aquifer was assessed to be minimal. (Martin) However, several other possibilities were noted:

1. That degraded water resulting from retorting activities could be transported upward into the root zone of the vegetal community, and

- (a) endanger vegetation, or

- (b) introduce undesirable constituents into the food web.

2. That, if lateral movement of perched and fracture waters, was taking place, contaminants could be introduced to the surface and the watershed. (Martin)

The objectives of GKI water quality studies are:

1. Generate reliable background data on the chemical characteristics of the groundwater in the areas which may become associated with the retorting process;
2. Produce and evaluate data on the chemical characteristics of waters generated by in situ retorting of oil shale;
3. Determine and quantify the effects and their extent that in situ retorting might have upon ground and surface waters;
4. Assess the degree of probability that contaminants emitted or left in place by retorting may be transported by natural hydrologic processes to areas beyond those of immediate development; and
5. Develop cost-effective and environmentally sound means of disposing of waters produced by in situ retorting.

This report addresses objectives 1 and 2 of the GKI water quality studies within the limits of currently available data.

#### SAMPLE SELECTION

Very restrictive analytical definitions were developed to describe groundwater and GKI retort water in an effort to eliminate from the sample population both groundwater samples contaminated by retorting and retort water samples diluted by groundwater. Within the limits imposed by sample variability and sample numbers, this maximized the probability of adequately characterizing both types of water and detecting their differences since most ambiguous samples were eliminated from analytical consideration. The definitions utilized were as follows:

Native Groundwater: Water taken from a well located more than 200 yards from a retort that has been blasted. It is presumed not to have been affected by retorting.

Retort Water: Water collected from a retort at or after the time when clean oil production has reached or exceeded 1.5 bbls/day per 100 square feet of retort cross section. This is intended to provide a sample base of water produced when a retort is fully operational, and exclude water that was contained in a retort prior to oil production.

#### WATER SAMPLE DATABASE

Groundwater: Of the water samples collected and analyzed to date, eight can be considered native groundwater. Groundwater samples were collected irregularly in 1978 and 1979: one sample was collected on January 24, 1978; another on May 3, 1978; two on July 31, 1978; and the other four on February 12, 1979. Three of the samples were taken from ERDA/DOE Core Hole #5, which was drilled to a depth of approximately 138 feet. The other five samples were taken from different wells of the GKI series 200 hydrologic study wells which were drilled to the mahogany marker

of the local oil shale and surface cased with PVC plastic. Figure 1, which follows, shows the location of these wells on Section 2.

Groundwater samples were taken using Bacon bomb sampling apparatus or improvised sample bombs. Six liters of water were collected for each groundwater sample, and were taken in increments due to the limited capacity of the sampling devices. No consistent sampling procedures were followed.

Groundwater samples collected in 1978 were shipped to Ford Chemical Laboratory, Inc., in Salt Lake City, Utah, for analysis. The four samples taken on February 12, 1979, were collected directly in prepared bottles, promptly refrigerated and later analyzed at the GKI field laboratory.

Retort Water: Samples of retort water were collected from three retorts at irregular intervals over a six-month period. One sample was taken from the south production well of Retort #15. Five samples from Retort #14 were collected at the drain from the bottom of the retort's north 400 barrel heated storage tank. Five samples from Retort #16 were collected from a tap on the production line next to one of the production well pumps. Figure 2, which follows, shows the location of the retorts mentioned.

All retort water samples available at the time of this report had been analyzed by Ford Laboratory.

#### SAMPLING ERROR EVALUATION

Several possible errors in the data collected and attributable to sampling procedures or techniques have been noted.

The possibility exists that the groundwater samples obtained had stagnated in the wells. Contamination of some groundwater samples is also suspected. For example: Samples collected from ERDA/DOE Core Hole #5 and GKI Well 200 on July 31, 1978, were taken with the same sampling devices used earlier that day to collect samples from wells peripheral to Retort #15, which contained some oil. Those groundwater samples contained high levels of oil and grease, and were excluded from the determination of the mean for groundwater oil and grease.

The two retort water samples taken from the Retort #14 oil storage tank on March 22, 1978, contained a small amount of Baroid Drop 2002 emulsion breaker, which had been added to the tank before collection of the samples. Drop 2002 was added to a 50 percent oil/water emulsion at a rate of one part to 10,000 parts emulsion.

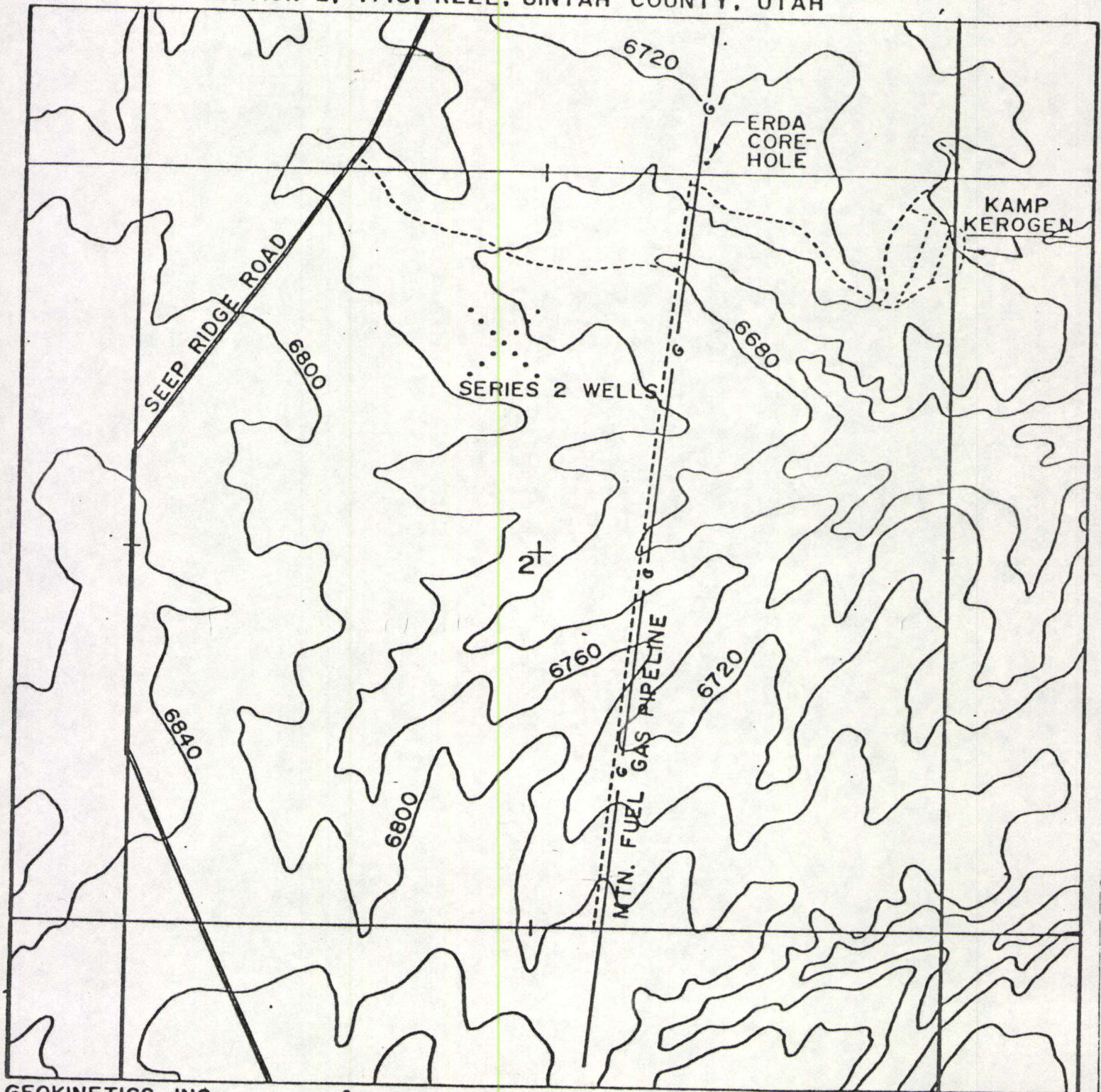
#### CHEMICAL ANALYSIS METHODS

Extensive research by others has shown that "standard analytical methods including Standard Methods, EPA methods, ASTM methods, and USGS methods are often not applicable to these types of (retort) waters due to interference and the extremely high or low levels of many

Figure 1

SERIES 2 HYDROLOGICAL STUDIES WELLS

SECTION 2, T14S, R22E, UINTAH COUNTY, UTAH



GEOKINETICS INC.

LEGEND

• HYDROLOGICAL STUDY WELL



0 500' 1000' 2000'  
-5- SCALE

KG

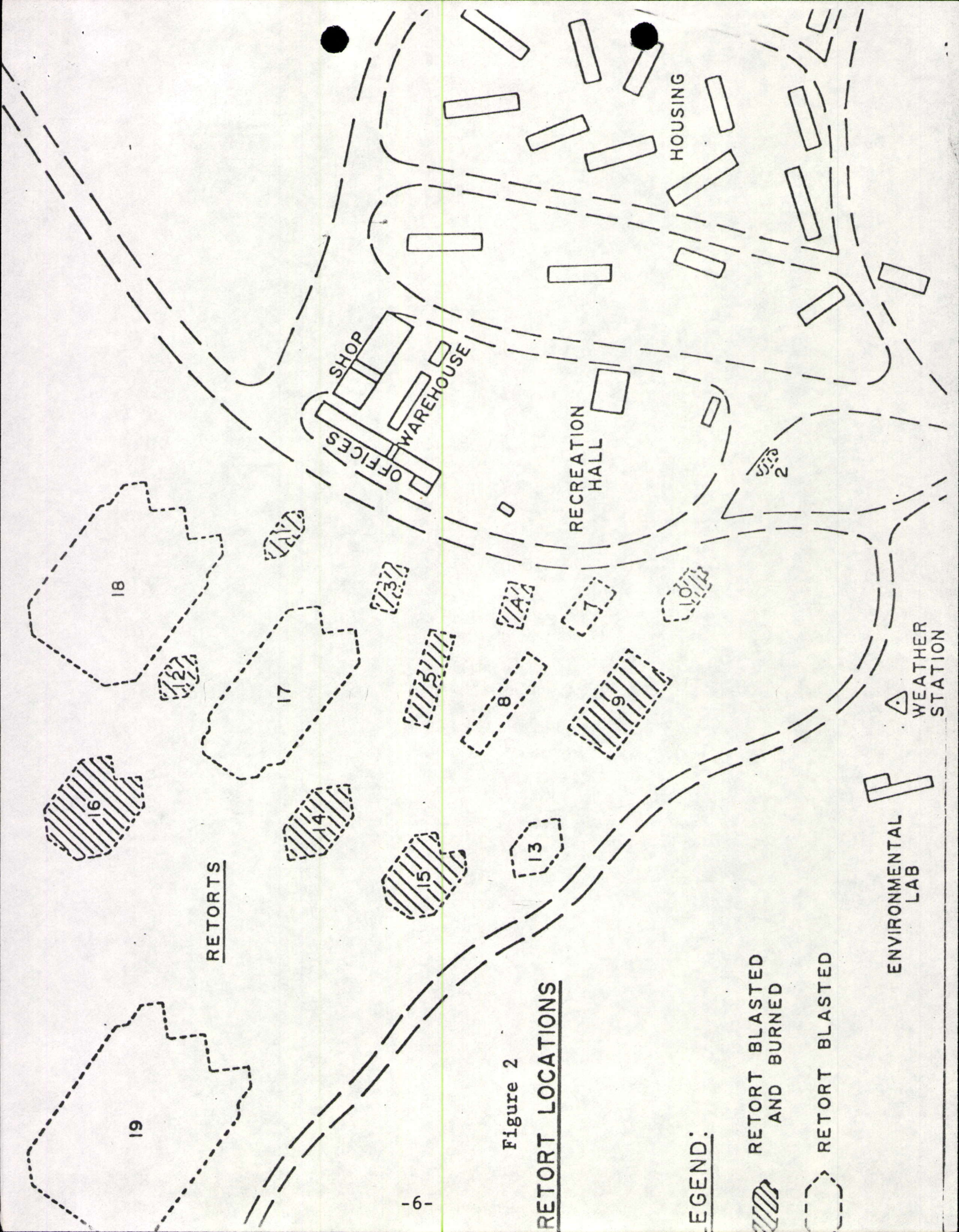

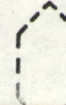


Figure 2  
RETORT LOCATIONS

LEGEND:

-  RETORT BLASTED AND BURNED
-  RETORT BLASTED

parameters." (Fox and others, 1978) "The wide variations in analytical results...reflect the often-observed inadequacy of current available techniques to provide accurate, precise and, thus useful, analytical data for similar type samples..." (Farrier and others, 1978)

The analytical methods used by Ford Laboratory are detailed in Appendix B and methods used by GKI are detailed in Appendix C.

### STATISTICAL ANALYSES

The first steps in the statistical analytical process employed was the derivation of the mean, or average, standard deviation and variance for each parameter tested. The specific formulas used to derive these figures are shown in Appendix D. The mean value, standard deviation, variance, high and low value for each parameter of the eight groundwater samples are shown in Table 1. The same information for the 11 retort water samples is shown on Table 2.

The next step was to determine the adequacy of the n-size available; "n" being the number of samples tested for each parameter. This gives an indication of the number of samples needed to achieve adequate approximations of the population means of the waters in question.

Table 3 is included to show the relatively low quality of the native groundwater and retort water tested. Both types of water appear to be unsuitable for human consumption or domestic use, stock watering, irrigation or industrial process use. (Walton; Golden, et al) In the case of several constituents, it appears that groundwater could be more toxic than retort water (ex.-fluoride, selenium).

Two methods were used to estimate the sample sizes required to approximate the population means with an error of estimation less than 10 percent, approximately 95 percent of the time. The first method used is determined by the mean and the range of a given parameter, based on the empirical rule that one standard deviation equals roughly one-quarter of the range between the high value and the low value. The second method utilized is computed from the mean and the standard deviation of a given parameters, and results in a more conservative and realistic estimate of the required n-size. The formulas for each method are listed in Appendix E.

Table 4 shows the range of the sample size desirable to have for each parameter, as estimated with these methods. These figures indicate that, with the exception of pH and possibly Fluoride, the data available is generally insufficient for meaningful characterizations of native groundwater and retort water population means.

Because of the limited number of samples available and wide variation found for some parameters, it cannot be inferred that a large difference in the sample means of a parameter indicates a significant difference in the two groups for the parameter in question.

TABLE 1

STATISTICAL CHARACTERIZATION OF NATIVE GROUNDWATER, BASED ON  $n=8$ , UNLESS OTHERWISE NOTED.  
ALL CONCENTRATIONS EXPRESSED AS mg/l, UNLESS OTHERWISE NOTED.

n-Size	Parameter	Mean	Standard Deviation	Variance	High	Low
	Alkalinity as $\text{CaCO}_3$	25,217.5	7,607.81	50,643,943	37,460	16,000
	Hardness as $\text{CaCO}_3$	39.28	10.32	93.17	50	21.8
	pH units	9.33	0.20	0.04	9.67	8.99
	Conductivity $\mu\text{mhos. cm}^{-1}$	36,323.75	6,884.55	41,472,448	44,900	22,400
	OOD	6,090.75	5,497.07	26,440,597	16,434	2,016
	Ammonia as $\text{NH}_3\text{-N}$	24.54	13.71	164.36	42.6	3.5
	Bicarbonate as $\text{HCO}_3$	25,961.88	8,968.82	70,384,749	38,180	11,468
	Carbonate as $\text{CO}_3$	2,383.25	2,050.76	3,679,928	4,060	0
	Chloride as Cl	2,223.13	1,450.33	1,840,518	4,800	20
	Cyanide as CN	0.11	0.09	0.008	0.29	0
	Nitrate as $\text{NO}_3\text{-N}$	6.21	6.69	39.17	14.4	0
	Nitrite as $\text{NO}_2\text{-N}$	0.39	0.57	0.29	1.6	0
	Phenol	0.193	0.203	0.036	0.43	0
	Phosphate-total	5.02	3.36	9.91	11.32	1.88
	Phosphate-ortho	2.17	1.52	2.02	4.265	0.05
	Sulfate as $\text{SO}_4$	11,143.88	11,368.43	113,086,058	23,413	92
	Sulfide as S	16.95	21.98	422.87	57.6	1.18
6	Oil & Grease	3.33	2.34	4.56	6.2	0
4	Surfactants as MBAS	4.31	2.93	6.45	6.4	0
	Total Dissolved Solids	37,648.13	16,846.26	248,321,965	64,068	21,200
4	Gross Alpha $\pm 3.5\text{pCi.l}^{-1}$	6.18	1.31	1.29	8.0	5.0
4	Gross Beta $\pm 5.0\text{pCi.l}^{-1}$	17.75	5.68	24.19	24.0	12.0
6	Antimony as Sb	0.24	0.221	0.041	0.6	0.007
	Arsenic as As	0.46	0.40	0.140	0.8	0.040
	Barium as Ba	0.71	0.528	0.244	1.96	0.36
6	Beryllium as Be	0.009	0.005	0.00002	0.014	0
6	Bismuth as Bi	0.30	0.31	0.078	0.7	0.008
4	Bromide as Br	0.152	0.103	0.008	0.25	0.016
4	Boron as B	87.85	174.77	22,907.60	350	0.24
	Cadmium as Cd	0.14	0.36	0.11	1.02	0
	Calcium as Ca	7.11	5.99	31.42	20.0	0
6	Chromium as Cr	0.10	0.12	0.01	0.28	0.02
	Cobalt as Co	0.28	0.35	0.107	1.12	0.01
	Copper as Cu	0.20	0.13	0.015	0.52	0.11
4	Fluoride as F	93.3	19.93	298.01	123	80.8
4	Germanium as Ge	0.009	0.011	0.00008	0.022	0
	Iron as Fe	13.18	19.88	345.98	56	0.73
	Lead as Pb	0.17	0.107	0.01	0.349	0.04
	Lithium as Li	0.24	0.076	0.005	0.35	0.136
	Magnesium as Mg	12.79	14.18	175.91	40	2.05
4	Manganese as Mn	0.383	0.513	0.197	1.15	0.086
4	Mercury as Hg $\mu\text{g.l}^{-1}$	0.7	1.4	1.47	2.8	0
	Molybdenum as Mo	0.41	0.221	0.041	0.68	0.14
	Nickel as Ni	0.43	0.509	0.227	1.62	0.05
	Potassium as K	53.80	24.63	530.60	88	19.91
	Selenium as Se	0.97	1.38	1.66	4.22	0
4	Silica as $\text{SiO}_2$	28.6	16.58	206.16	46.5	14
4	Silver as Ag	0.041	0.031	0.0007	0.078	0.012
	Sodium as Na	10,455.38	2,877.39	7,294,884	13,803	4,380
4	Strontium as Sr	0.035	0.024	0.0004	0.05	0
4	Tin as Sn	0	0	0	0	0
4	Vanadium as V	0.31	0.1	0.008	0.42	0.18
	Zinc as Zn	0.15	0.133	0.015	0.456	0.043

TABLE 2

STATISTICAL CHARACTERIZATION OF RETORT WATER, BASED ON  $n=11$ , UNLESS OTHERWISE NOTED.  
ALL CONCENTRATIONS EXPRESSED AS mg/l, UNLESS OTHERWISE NOTED.

n-Size	Parameter	Mean	Standard Deviation	Variance	High	Low
	Alkalinity as $\text{CaCO}_3$	17,836.36	4,373.39	17,387,768	30,300	15,000
	Hardness as $\text{CaCO}_3$	153.72	85.75	6,684.20	303	28
	pH units	8.56	0.34	0.10	9.08	8.14
	Conductivity $\mu\text{mhos.cm}^{-1}$	34,035.91	10,968.05	109,362,003	64,800	24,600
	COD	3,682.36	650.57	384,764	4,420	2,000
	Ammonia as $\text{NH}_3\text{-N}$	1,270.68	779.52	552,415	2,400	65.2
	Bicarbonate as $\text{HCO}_3$	17,174.91	7,152.98	46,513.803	36,996	11,346
	Carbonate as $\text{CO}_3$	2,825.45	1,567.70	2,234,261	4,560	0
	Chloride as Cl	3,016.36	4,292.25	16,748,550	15,000	800
	Cyanide as CN	13.31	9.55	82.89	25.3	0.94
	Nitrate as $\text{NO}_3\text{-N}$	34.16	28.15	720.25	76	2.5
	Nitrite as $\text{NO}_2\text{-N}$	1.33	1.13	1.17	3.6	0.18
	Phenol	11.56	11.84	127.50	26.48	0.10
	Phosphate-total	2.1	1.22	1.34	3.82	0.50
	Phosphate-ortho	1.07	0.80	0.58	2.26	0.02
	Sulfate as $\text{SO}_4$	609.09	361.71	118,942	1,020	184
	Sulfide as S	447.36	280.72	71,641.55	816	34.8
	Oil & Grease	103	202.00	37,095.68	697.8	7.9
	Surfactants as MBAS	23.20	34.39	1,075.35	110	0
	Total Dissolved Solids	22,144.64	7,133.03	46,254,620	23,500	16,052
	Gross Alpha $\pm 3.5\text{pCi.l}^{-1}$	8.29	4.21	16.13	14	3.8
	Gross Beta $\pm 5.0\text{pCi.l}^{-1}$	26.45	6.74	41.34	38	21
5	Antimony as Sb	0.011	0.003	0.000006	0.015	0.008
	Arsenic as As	2.55	3.92	13.96	13.485	0.21
	Barium as Ba	0.54	0.18	0.03	0.82	0.30
5	Beryllium as Be	0.009	0.006	0.00003	0.016	0
5	Bismuth as Bi	0.059	0.017	0.0002	0.088	0.046
	Bromide as Br	0.18	0.10	0.01	0.4	0.1
	Boron as B	60.55	67.63	4,157.52	175	0.51
	Cadmium as Cd	0.084	0.088	0.007	0.2	0.001
	Calcium as Ca	32.58	33.25	1,005.19	101.7	0.12
5	Chromium as Cr	0.078	0.039	0.001	0.144	0.046
	Cobalt as Co	0.56	0.30	0.08	1.272	0.246
	Copper as Cu	0.209	0.167	0.025	0.504	0.026
	Fluoride as F	35.15	6.47	38.10	44.3	25.0
	Germanium as Ge	0.044	0.096	0.008	0.28	0
	Iron as Fe	13.99	25.46	589.10	88.20	1.54
	Lead as Pb	0.642	0.924	0.776	2.24	0.015
	Lithium as Li	0.179	0.117	0.012	0.378	0.070
	Magnesium as Mg	17.49	7.75	54.56	26.4	6.86
	Manganese as Mn	0.937	1.876	3.20	4.74	0.038
	Mercury as $\text{Hg } \mu\text{g.l}^{-1}$	3.78	11.35	117.18	38	0
	Molybdenum as Mo	11.91	8.74	69.49	24.4	2.05
	Nickel as Ni	1.62	2.06	3.85	5.21	0.067
	Potassium as K	121.43	21.16	407.10	147.8	99.2
	Selenium as Se	0.215	0.470	0.20	1.238	0
	Silica as $\text{SiO}_2$	17.95	4.15	15.65	25	13.5
	Silver as Ag	0.135	0.123	0.014	0.316	0.004
	Sodium as Na	9,392	2,951.0	7,916,720	17,800	7,281
	Strontium as Sr	0.002	0.003	0.000008	0.007	0
	Tin as Sn	0.168	0.454	0.187	1.5	0
	Vanadium as V	0.43	0.25	0.056	0.82	0.12
	Zinc as Zn	0.095	0.067	0.004	0.242	0.03

TABLE 3

MEAN CONCENTRATIONS FOR GROUNDWATER AND RETORT WATER COMPARED TO "NORMAL"  
GROUNDWATER AND EXISTING WATER QUALITY STANDARDS.

Parameter	Groundwater	Retort Water	"Normal" Groundwater* (as ppm)	Maximum Concentrations Considered Safe for Human** Ingestion
Alkalinity as CaCO <sub>3</sub>	25,217.5	17,836.36		20-500+
Hardness as CaCO <sub>3</sub>	39.28	153.72		95-150
pH units	9.33	8.56		6-9
Ammonia as NH <sub>3</sub> -N	24.54	1,270.68		0.4-1.5
Bicarbonate as HCO <sub>3</sub>	25,961.88	17,174.91	1.0-1,000	
Carbonate as CO <sub>3</sub>	2,383.25	2,825.45	0.01-10.0	
Chloride as Cl	2,223.13	3,016.36	1.0-1,000	250
Cyanide as CH	0.11	13.31		0.005-0.2
Nitrate as NO <sub>3</sub> -N	6.21	34.16	0.01-10.0	45
Phenol	0.193	11.56		0.0001-0.001
Phosphate-total	5.02	2.1	<0.1	0.03-0.4
Sulfate as SO <sub>4</sub>	11,143.88	609.09	1.0-1,000	250
Oil & Grease	3.33	103		0-15
Total Dissolved Solids	37,648.13	22,144.64		100-1,000
Gross Alpha $\pm 3.5\text{pCi.l}^{-1}$	6.18	8.29		3 pCi/l
Gross Beta $\pm 5.0\text{pCi.l}^{-1}$	17.75	26.45		100-1,000 pCi/l
Arsenic as As	0.46	2.55	<0.1	0.01
Barium as Ba	0.71	0.54	<0.1	1.0
Beryllium as Be	0.009	0.009	<0.001	
Bismuth as Bi	0.30	0.059	<0.001	
Bromide as Br	0.152	0.18	<0.1	
Boron as B	87.85	60.55	<10	0.5-1.0
Cadmium as Cd	0.14	0.084	<0.1	0.01
Calcium as Ca	7.11	32.58	1.0-1,000	
Chromium as Cr	0.10	0.078	<0.1	0.05
Cobalt as Co	0.28	0.56	<0.1	0.2
Copper as Cu	0.20	0.209	<0.1	0.02-1.0
Fluoride as F	93.3	35.15	0.01-10.0	0.7-5
Germanium as Ge	0.009	0.044	<0.1	
Iron as Fe	13.18	13.99	0.01-10.0	0.3
Lead as Pb	0.17	0.642	<0.1	0.05
Lithium as Li	0.24	0.179	<0.1	
Magnesium as Mg	12.79	17.49	1.0-1,000	
Manganese as Mn	0.383	0.937	<0.1	0.05
Mercury as Hg $\mu\text{g.l}^{-1}$	0.7	3.78		0.005
Molybdenum as Mo	0.41	11.91	<0.1	
Nickel as Ni	0.43	1.62	<0.1	
Potassium as K	53.80	121.43	0.01-10.0	
Selenium as Se	0.97	0.215	<0.1	0.01-0.5
Silver as Ag	0.041	0.135	<0.001	0.005-0.05
Sodium as Na	10,455.38	9,392	1.0-1,000	
Strontium as Sr	0.035	0.002	0.01-10.0	
Tin as Sn	0	0.168	<0.001	
Vanadium as V	0.31	0.43	<0.1	
Zinc as Zn	0.15	0.095	<0.1	0.01-5

All concentrations expressed as mg/l, unless otherwise noted.

\* Walton, pp 456-464.

\*\* Golden, et al., pp 462-480.

TABLE 4

RANGE OF SAMPLES NEEDED TO APPROXIMATE POPULATION MEANS TO WITHIN 10%  
OF THEIR ACTUAL VALUE, 95% OF THE TIME.

PARAMETER	GROUNDWATER		RETORT WATER	
	N Method 1	N Method 2	N Method 1	N Method 2
Alkalinity as $\text{CaCO}_3$	19	37	19	25
Hardness as $\text{CaCO}_3$	13	28	81	125
pH units	1	1	1	1
Conductivity	10	15	35	42
COD	141	326	11	13
Ammonia as $\text{NH}_3\text{-N}$	64	125	85	151
Bicarbonate as $\text{HCO}_3$	27	48	56	70
Carbonate as $\text{CO}_3$	73	297	66	124
Chloride as Cl	116	171	555	810
Cyanide as CN	174	268	84	206
Nitrate as $\text{NO}_3\text{-N}$	135	465	116	272
Nitrite as $\text{NO}_2\text{-N}$	420	855	116	289
Phenol	125	443	131	420
Phosphate-total	89	179	63	136
Phosphate-ortho	95	197	110	224
Sulfate as $\text{SO}_4$	110	417	48	142
Sulfide as S	277	673	77	158
Oil & Grease	87	198	1,122	1,539
Surfactants	56	185	563	879
Total Dissolved Solids	33	81	3	42
Gross Alpha	6	18	38	104
Gross Beta	12	41	11	26
Antimony as Sb	157	348	10	28
Arsenic as As	69	303	678	946
Barium as Ba	128	223	24	45
Beryllium as Be	61	124	80	178
Bismuth as Bi	134	428	13	34
Bromide as Br	60	184	70	124
Boron as B	397	1,584	208	500
Cadmium as Cd	1,328	2,645	141	440
Calcium as Ca	198	284	244	417
Chromium as Cr	169	576	40	100
Cobalt as Co	393	284	244	417
Copper as Cu	106	169	131	256
Fluoride as F	6	19	8	14
Germanium as Ge	150	598	1,013	1,905
Iron as Fe	440	911	960	1,325
Lead as Pb	83	159	301	829
Lithium as Li	20	41	75	171
Magnesium as Mg	221	492	32	79
Manganese as Mn	193	718	630	1,604
Mercury as Hg	400	1,600	2,527	3,607
Molybdenum as Mo	44	117	89	216
Nickel as Ni	334	561	252	647
Potassium as K	41	84	5	13
Selenium as Se	474	810	829	1,912
Silica as $\text{SiO}_2$	33	135	11	22
Silver as Ag	65	229	134	333
Sodium as Na	21	31	32	40
Strontium as Sr	52	189	307	900
Tin as Sn			1,993	2,922
Vanadium as V	15	42	67	136
Zinc as Zn	188	311	125	199

An objective of this study was to determine whether any significant differences between native groundwater and retort water could be determined with the information available. This led to the hypothesis, to be proven or disproven for each parameter, that there is no difference in the population means ( $\mu 1$  and  $\mu 2$ ) of the two groups. The null hypothesis, the hypothesis to be proven or disproven, can be stated as  $(\mu 1 - \mu 2) = 0$ . The statistical "t" test was chosen as a means of proving or disproving the hypothesis due to the small sample n-sizes, and the fact that the "t" test is especially designed to use when n-size is less than 30. The formula used for the "t" test is described in Appendix F.

Application of the "t" test to the groundwater and retort water means for a parameter results in the acceptance or rejection of the hypothesis. Acceptance indicates that no significant difference between groundwater and retort water can be ascertained from the information available. Rejection of the hypothesis indicates that there is a statistically significant difference between the two means tested.

The groundwater and retort water means for each parameter were subjected to the "t" test. The results of this statistical testing are summarized in Table 5.

Based on the result of this evaluation and upon chemical peculiarities found in the course of laboratory analyses, certain parameters should be added to, and others deleted from, the analysis program.

#### ADDITIONS

Total sulfur should be determined in the samples because not all sulfur species are represented by sulfate. There are significant contributions from thiosulfate, tetrathionate and thiocyanate (SCN). There may also be some contribution from organic and inorganic sulfides. These species could be represented by a total sulfur analysis.

It has been noted that thiocyanate (SCN) is apparently a retorting specific chemical with potential as a natural retort water tracer. Therefore, it should also be added to the analytical test suite.

Total Kjeldahl nitrogen should be added to account for the organic nitrogen, particularly basic nitrogen which is more soluble in water. This, in addition to the analyses from ammonia, would give a better representation of the nitrogen compounds existing in retort and groundwater.

#### DELETIONS

Carbonate and bicarbonate should be deleted from the test suite since their effect is adequately measured by alkalinity. Also, laboratory experience indicates that the accuracy of the figures is adversely affected by high ammonia concentrations. Furthermore, the two parameters are not markedly toxic and do not appear to be increased by retorting activity.

TABLE 5

RESULTS OF THE "t" TEST AS APPLIED TO GROUNDWATER  
AND RETORT WATER MEANS FOR EACH PARAMETER.

Parameters Showing a Statistically Significant Difference at the 99% Confidence Range:

Concentrations Higher  
in Groundwater:

pH  
Sulfate  
Total Dissolved Solids  
Fluoride  
Strontium

Concentrations Higher  
in Retort Water:

Hardness  
Ammonia  
Cyanide  
Sulfide  
Molybdenum  
Potassium

Parameters Showing a Statistically Significant Difference at the 90% Confidence Range:

Concentrations Higher  
in Groundwater:

Alkalinity  
Bicarbonate  
Phosphate-total  
Phosphate-ortho  
Antimony  
Cobalt  
Selenium

Concentrations Higher  
in Retort Water:

Nitrate  
Nitrite  
Phenol  
Gross Beta  
Calcium

Nitrite and ortho-phosphate should also be deleted. Nitrite appears to be directly related to nitrate levels, is in light concentration, is not an important health hazard, can be expected to oxidize to nitrate when exposed to the atmosphere and provides little valuable information. Ortho-phosphate concentration appears to be related to total phosphate concentration, is not an important health hazard, does not appear to increase due to retorting, and the testing procedures available do not consistently give satisfactory results.

The level of gross beta appears to increase due to retorting, probably due to the concomitant increase in potassium concentrations. However, the levels found are well below recommended safety maximums, and can likely be monitored indirectly by testing for potassium.

Finally, bismuth, bromide, germanium, lithium, nickel, tin and vanadium are nearly non-toxic and are found in insignificant quantities that do not justify continued monitoring.

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APPENDIX A

DATES AND SOURCES OF WATER SAMPLES USED IN THIS STUDY

<u>Date</u>	<u>Source/Location</u>	<u>Sample #</u>	<u>Type</u>
1-24-78	ERDA/DOE Core Hole #5	8004	Groundwater
5- 3-78	ERDA/DOE Core Hole #5	8073	"
7-31-78	ERDA/DOE Core Hole #5	8106	"
7-31-78	Well - 200	8107	"
2-12-79	Well - 213	9080	"
2-12-79	Well - 223	9081	"
2-12-79	Well - 233	9083	"
2-12-79	Well - 243	9083	"
3-12-78	Retort - 14	8010	Retort
3-16-78	Retort - 14	8012	"
3-22-78	Retort - 14	8015	"
3-22-78	Retort - 14	8017	"
3-30-78	Retort - 14	8022	"
6- 3-78	Retort - 15	8100	"
9- 5-78	Retort - 16	8126	"
9- 6-78	Retort - 16	8127	"
9- 7-78	Retort - 16	8128	"
9- 8-78	Retort - 16	8129	"
9- 9-78	Retort - 16	8130	"

## APPENDIX B

THE ANALYTICAL METHODS USED BY THE FORD CHEMICAL LABORATORY, INC.  
ARE LISTED BELOW IN CONDENSED FORM:

Parameter	Unit	Method	1974 EPA Methods	14th Ed. Standard Methods
Alkalinity, as CaCO <sub>3</sub>	mg/l	Manual or automated electrometric titration to 4.5 pH, or automated method	3 5	278 ---
Ammonia, as N	mg/l	Manual distillation (at pH 9.5) followed by nesslerization, titration, electrode, automated phenolate	--- 159 165 168	410 412 --- ---
BOD, 5 day	mg/l	Winkler (azide modification) or electrode method	---	543
COD	mg/l	Dichromate reflux	20	550
Chloride	mg/l	Silver nitrate, mercuric nitrate, or automated colorimetric	--- 29 31	303 304 613
Chlorine, total residual	mg/l	Iodometric titration, amper- ometric or starch-iodine end- point; DPD colorimetric or ti- trimetric methods	--- 35 --- ---	318 322 332 332
Cyanide, total	mg/l	Distillation followed by silver nitrate titration or pyridine pyrazolone (or barbituric acid) colorimetric	40	361
Cyanide amenable to chlorination	mg/l	Distillation followed by silver nitrate titration or pyridine pyrazolone (or barbituric acid) colorimetric	49	376
Dissolved Oxygen	mg/l	Winkler (azide modification) or electrode method	51 56	443 450
Fluoride	mg/l	Distillation followed by ion electrode: SPANDS; or automated complexone	--- 65 59 61	389 391 393 164

APPENDIX B (Continued)

Parameter	Unit	Method	1974 EPA Methods	14th Ed. Standard Methods
Hydrogen ion (pH)	Units	Electrometric measurement	239	460
Kjeldahl Nitrogen as N	mg/l	Digestion and distillation followed by nesslerization, ti- tration, or electrode; automated digestion automated phenolate	175 165 182	437 --- ---
<u>METALS</u>				
Aluminum	mg/l	Digestion followed by atomic absorption or colorimetric	--- 92	171 152
Arsenic	mg/l	Digestion followed by silver diethyldithiocarbonate; or atomic absorption	--- 9 95	285 283 159
Beryllium	mg/l	Digestion followed by atomic absorption or colorimetric	--- 99	177 152
Boron	mg/l	Colorimetric (curcumin)	13	287
Cadmium	mg/l	Digestion followed by atomic absorption or colorimetric	101 ---	148 182
Calcium	mg/l	Digestion followed by atomic absorption or colorimetric	103 ---	148 182
Chromium, VI	mg/l	Extraction and atomic absorption; colorimetric	89 105	--- 192
Chromium	mg/l	Digestion followed by atomic ab- sorption or colorimetric	105 ---	148 192
Cobalt	mg/l	Digestion followed by atomic absorption	107	148
Copper	mg/l	Digestion followed by atomic absorption or colorimetric	108 ---	148 196
Iron	mg/l	Digestion followed by atomic absorption or colorimetric	110 ---	148 196
Lead	mg/l	Digestion followed by atomic absorption or colorimetric	112 ---	148 215

APPENDIX B (Continued)

<u>Parameter</u>	<u>Unit</u>	<u>Method</u>	<u>1974 EPA Methods</u>	<u>14th Ed. Standard Methods</u>
Magnesium	mg/l	Digestion followed by atomic absorption; or gravimetric	114 ---	148 221
Manganese	mg/l	Digestion followed by atomic absorption or colorimetric	116 ---	148 225, 227
Mercury	mg/l	Flameless atomic absorption	118	156
Nickel	mg/l	Digestion followed by atomic absorption or colorimetric	141 ---	148 232
Potassium	mg/l	Digestion followed by atomic absorption, colorimetric or flame photometric	143 --- ---	--- 235 234
Selenium	mg/l	Digestion followed by atomic absorption	145	159
Sodium	mg/l	Digestion followed by atomic absorption, flame photometric	147 ---	--- 250
Tin	mg/l	Digestion followed by atomic absorption	150	---
Titanium	mg/l	Digestion followed by atomic absorption	151	---
Zinc	mg/l	Digestion followed by atomic absorption or colorimetric	155 ---	148 265
Nitrate, as N	mg/l	Cadmium reduction, brucine sulfate; automated cadmium or hydrazine reduction	201 197 207	423 427 620
Nitrite, as N	mg/l	Manual or automated colorimetric	215	434
Oil & Grease	mg/l	Liquid extraction with freon-gravimetric	229	515
Organic Carbon Total	mg/l	Combustion - infrared	236	532
Strontium	mg/l	Digestion followed by atomic absorption	---	257
Vanadium	mg/l	Digestion followed by atomic absorption	---	259

APPENDIX B (Continued)

<u>Parameter</u>	<u>Unit</u>	<u>Method</u>	<u>1974 EPA Methods</u>	<u>14th Ed. Standard Methods</u>
Lithium	mg/l	Digestion followed by atomic absorption	---	219
Silver	mg/l	Digestion followed by atomic absorption	---	242
Total Hardness	mg/l	EDTA Titration	---	202
Barium	mg/l	Digestion followed by atomic absorption	---	152
Bromide	mg/l	Colorimetric	14	291
Molybdenum	mg/l	Digestion followed by atomic absorption	139	---
Germanium	mg/l	Colorimetric	---	---
Antimony	mg/l	Digestion followed by atomic absorption	94	---
Bismuth	mg/l	EDTA Colorimetric	---	---
Silica	mg/l	Colorimetric	---	490
Surfactants	mg/l	Methylene Blue	---	512
Phenol	mg/l	Distillation chloroform extraction colorimetric	---	577
Orthophosphate, as P	mg/l	Manual or automated ascorbic acid reduction	249 256	481 624
Phenols	mg/l	Colorimetric, (4-AAP)	241	582
Phosphorus, total as P	mg/l	Persulfate digestion followed by manual or automated ascorbic acid reduction	249 256	476,481 624
Solids, Total	mg/l	Gravimetric, 103 to 105°C	270	91
Solids, Diss.	mg/l	Glass fiber filtration, 180°C	266	92
Solids, Susp.	mg/l	Glass fiber filtration, 105°C	268	94

APPENDIX B (Continued)

<u>Parameter</u>	<u>Unit</u>	<u>Method</u>	<u>1974 EPA Methods</u>	<u>14th Ed. Standard Methods</u>
Specific Cond. at 25°C	micro mhos/cm	Wheatstone bridge	275	71
Sulfate	mg/l	Gravimetric; turbidimetric; or automated colorimetric	--- 277, 279	493 496
Sulfide	mg/l	Titrimetric-Iodine; Methylene blue photometric	284 ---	505 503
Turbidity	NTU	Nephelometric	295	132

## APPENDIX C

THE WATER QUALITY ANALYSIS METHODS USED BY GKI ARE IDENTICAL TO  
THOSE USED BY FORD CHEMICAL LABS, EXCEPT AS LISTED BELOW:

### GKI METHODS OF WATER ANALYSIS

Parameter	Method	Page Reference in 14th Ed. Standard Methods
Total Alkalinity	Manual titration to pH 4.5	278
Ammonia as N	Distillation then measurement by electrode	410,417
BOD	Not done at GKI	
COD	Silver catalyzed dichromate reflux	550
Chloride	Mercuric nitrate with preliminary oxidation or argentometric titration	304,303
Chlorine, residual	Done only on tap water	
Cyanide	Distillation followed by ion-sensing electrode	367,365,372
Dissolved O	Not done at GKI	
Al, Be, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Ni, K Na, Sn, Ti, Zn, Sr, V, Li, Ag, Ba, Mo, Sb, Bi, Si	Digestion followed by AAS	
As, Cd, Hg, Se, Ge	AAS directly with no digestion	
Nitrate - N	Cadmium red or brucine sulfate colorimetric	423,427
Nitrite - N	Colorimetric direct	434
Oil & Grease	Instrumental	
Org. Carbon	Not done at GKI	
Total Phosphate	Sulfuric acid-nitric acid digestion followed by stannous chloride extraction or molybdate colorimetric	474,476,479

APPENDIX C (Continued)

<u>Parameter</u>	<u>Method</u>	<u>Page Reference in 14th Ed. Standard Methods</u>
Phenols	Colorimetric	582
Total Dissolved Solids	Gravimetric 180°C	208B
Total Suspended Solids	Gravimetric 105°C	208B
Conductivity	Wheatstone bridge	71
Sulfate	Gravimetric	493
Total Sulfur	Br <sub>2</sub> Oxidation	493
Thiocyanate	Colorimetric Fe <sup>ttt</sup>	383
Sulfide	Titrimetric-iodine	505
Turbidity	Nephelometric	132

Source: L. Morriss, Lab Supervisor, GKI

## APPENDIX D

METHODS OR FORMULAS USED TO DERIVE MEANS, STANDARD DEVIATION AND VARIATION FIGURES FOR GROUNDWATER AND RETORT WATER:

$$\text{Mean} = \bar{X} = \frac{\sum_{i=1}^n X_i}{n}, \quad l = 1, 2, 3, \dots, n$$

FORMULA USED TO CALCULATE THE STANDARD DEVIATION (s) OF THE X ARRAY USING n - 1 WEIGHTING:

$$s = \sqrt{\frac{vn}{n - 1}}$$

FORMULA USED TO CALCULATE THE VARIANCE (v) OF THE X ARRAY USING n WEIGHTING:

$$v = \frac{\sum X_i^2}{n} - \frac{(\sum X_i)^2}{n^2}$$

Source: Texas Instruments SR-51-II Owners Manual, Copyright 1976.

## APPENDIX E

FORMULAS FOR ESTIMATING NUMBER OF SAMPLES NEEDED TO APPROXIMATE  
POPULATION MEANS TO WITHIN 10% OF THEIR ACTUAL VALUE, 95% OF THE TIME:

### Definitions:

- $\mu$  = population mean  
 $\bar{X}$  = mean of test samples  
H = high value of test samples  
L = low value of test samples  
B = maximum value allowed between  $\bar{X}$  and  $\mu$  or  $B \geq \bar{X} - \mu$   
P = B expressed as a percentage of  $\bar{X}$ , e.g.  $P = .1\bar{X}$   
n = minimum sample size for accuracy desired  
s = standard deviation of test samples  
 $\sigma^2$  = population variance
- 

Method 1 - given mean and range of the test samples

$$n = \frac{4s^2}{(P\bar{X})^2} \text{ where } s = \frac{H-L}{4} \text{ derived from } n = \frac{4\sigma^2}{B^2}$$

---

Method 2 - given mean and standard deviation of test samples

$$n = \frac{4s^2}{(P\bar{X})^2} \text{ derived from } n = \frac{4\sigma^2}{B^2}$$

---

Source: Mendenhall, et al., pp. 220-221.

## APPENDIX F

THE "t" TEST USED FOR COMPARING TWO MEANS IS AS FOLLOWS:

Null Hypothesis:  $(\mu_1 - \mu_2) = 0$

Alternative Hypothesis:  $\mu_1 \neq \mu_2$  (for a two-tailed test)

Test Statistic:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{s \sqrt{1/n_1 + 1/n_2}}$$

where

$$s = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}}$$

Rejection Region: Reject if  $t$  is greater than  $t_a$  or less than  $-t_a$ , where  $a = \alpha/2$  and  $t$  is based on  $(n_1 + n_2 - 2)$  degrees of freedom.

$n$  = number of samples tested

$\bar{X}$  = sample mean

$\mu$  = population mean

Source: Mendenhall, et. al., pp. 308.

INTEROFFICE MEMORANDUM

DATE: April 4, 1979  
TO: Files  
FROM: H. Spradlin *WBS*  
SUBJECT: Groundwater Survey of Retort No. 20

During the month of March, a groundwater survey was conducted on Retort No. 20 utilizing 24 of the blastholes. For reference purposes, blasthole pattern design and other related information with respect to the layout of the retort can be obtained from the Retort No. 20 blast report (proprietary).

Over a period of one week, two separate investigations were conducted. The procedures for each were as follows:

1. On March 13, 1979 all wells were blown dry with well levels being monitored and recorded 24, 48, 72 and 144 hours thereafter; and
2. On March 19, 1979 all wells were blown dry with well levels being monitored and recorded 1, 4, 7, 10 and 24 hours thereafter.

The purpose of the initial investigation was to simply obtain general knowledge of the groundwater behavior. After noting a substantial increase in water levels after the first day, the second investigation was initiated in order to evaluate groundwater behavior during the first 24 hours after the wells had been blown.

The immediate findings of the initial investigation after six days of monitoring were as follows:

1. Of the 24 wells, 18 wells came to a common head at a mean elevation of 6685.4 feet with an extremely small standard deviation of 0.75 feet; and
2. The heads of the six anomalous wells ranged from approximately 15 feet below to 20 feet above the common average head of the 18 other wells; and

3. Of the 18 wells reaching a common head, all had varying fill rates.

Varying fill rates were confirmed by the second investigation which showed substantial differences in flow rates for all wells.

Information obtained from the concurrent Sandia camera study of adjacent wells showed that groundwater was flowing into the wells from cracks and fissures at 36 to 47 feet below the collar elevations. The study also showed that there were numerous dry cracks above and below the wet zone.

The findings are by no means conclusive nor can we expect them to be representative of the entire section, but we have been able to postulate a reasonable theory about groundwater behavior. After noting that during the spring thaw there is virtually no surface runoff, it is therefore postulated that the water is absorbed into the ground, flows in vertical fractures down to an impermeable layer, thereby forming an unconfined aquifer that is transported through a network of fractures and fissures.

In the case of Retort No. 20, the impermeable layer is approximately 47 feet below the surface. This could be the 2.5 inch mud seam that was noted in recent core studies conducted on the section. It has been calculated that if the mud seam does extend from the site of the core study to Retort No. 20, it would be at a subsurface elevation of about 6665 feet which conveniently corresponds to 47 feet below the surface of the retort.

It is also suspected that those anomalous wells with heads less than the common mean head have either constricted or congested fractures feeding them, thereby not allowing the wells to have reached the common head prior to the termination of the survey.

Those wells found to have heads greater than the common mean head are a bit more difficult to explain. A few suggested possibilities are:

1. A fracture from an area of greater head could be dissecting these particular wells.

2. A disrupted pocket of methane gas could have a temporary hydraulic effect on the column of water. During the survey, one well was noted to have surpassed the mean head by five feet; only to return to the mean head a few days later.

Page Three

In order to obtain further information from the collected data, the 18 wells with the common head were divided in half. A two-tailed T-test was used to determine if the mean common head of the up-dip wells was significantly different than the mean common head of the down-dip wells. The result was that there indeed was a significant difference.

This significant difference in means indicated that there was a general flow to the unconfined aquifer and that it was generally flowing up-dip. Since the standard deviations were extremely small, we were able to use vector analysis to obtain what is believed to be a fairly accurate direction of flow. The results indicated that water is flowing up-dip towards S17E.

It is suspected that during the spring the head of the unconfined aquifer is higher than the up-dip outcropping on the east side of Seep Ridge causing flow to the south. It is also suspected that later into the season and once the head drops below the up-dip outcropping that the observed flow will reverse itself and flow down-dip to the north.

In light of these findings and subsequent postulations, I recommend that further well designed surveys be conducted to either prove or disprove these preliminary findings.

gb

cc: Kamp  
Concord  
Vernal